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Monthly Progress Report

P-B1980-8

HERO SUPPORTING STUDIES

by

Norman P. Faunce
Paul F. Mohrbach

February 1 to February 28, 1963

Prepared for

U. S. NAVAL WEAPONS LABORATORY
Dahlgren, Virginia

Contract No. N178-8102

THE FRANKLIN INSTITUTE
LABORATORIES FOR RESEARCH AND DEVELOPMENT
PHILADELPHIA PENNSYLVANIA

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ABSTRACT

The protected MARK 7 MOD 0 ignition element ~~as evaluated by the Bruceton plan is found to~~ requires 0.451 and 1.158 w~~atts~~ of power to its leads respectively at 30 and 250 Mc for 50% probability of functioning. These data indicate that 5 db protection is afforded at 250 Mc while the sensitivity at 30 Mc differs little from its dc level.

Firing was attempted at 3 Gc, CW and pulsed power. Neither 154 watts of CW power nor 20 w~~atts~~, average, of pulsed power were able to bring about a functioning. Also with 10 w~~atts~~ at 3 Gc CW, applied for 10 min~~utes~~, not one of ten elements was apparently affected.

All data collected on this item relevant to its RF evaluation are presented~~, in summary form~~. This includes RF firing data from 10 Mc to 3 Gc for both the protected and standard elements, as well as the attenuation and base loss measurements in the same range of frequencies. ~~From this summary we concluded that additional tests at 1 Gc are in order, replacing tests planned at 3 Gc.~~

~~Finally~~ Results of attenuation measurements of a Ta ~~tantalum~~ capacitor are given. Within the 0.1 to 10 Mc range values between 2.5 to 15 db are obtained. Additional measurements are planned.

SUMMARY

All planned tests except one at dc have been completed this period on the protected MARK 7 MOD 0 ignition element. Precision firing tests at 30 and 250 Mc were performed and attempts were made to fire elements with CW and pulsed power at 3 Gc.

At 30 Mc we find the item to be little different from its sensitivity to dc, the required power being 451 mw as compared to 349 mw based on the cold dc resistance. At 250 Mc a 5 db loss causes the 50% firing point to be increased to 1.158 watts. At 3 Gc, we could not make the element function even though we pushed both systems to their limits which were 154 watts CW for 1 second, and 20 watts pulsed (average) for the normal 10 seconds. Even with 10 watts for CW power applied for 10 minutes at this frequency, we observed no effect.

Because of the failure to fire at 3 Gc we propose that additional tests be performed at 1 Gc. To check on earlier data we plan to perform a second sensitivity test, and to evaluate both cook-off and the effect of low level excitation for long duration at this frequency. This program on the protected MARK 7 element should be concluded next period and a testing program for the MARK 1 MOD 0 Squib and MARK 2 MOD 0 ignition element will then be commenced.

All of the evaluation data collected on the protected MARK 7 MOD 0 ignition element have been condensed in a summary in Section 2 of this report. We find very good agreement between predicted loss based upon a few measurements on a small sample of plug assemblies and the loss determined from firing tests at the expense of a large quantity of items.

Data showing the loss to be obtained from a tantalum capacitor have been reduced. A low of about 2.5 db is indicated at 1 Mc, but at 0.5, 5 and 10 Mc the loss is increased to 10 db. Additional measurement at intermediate points is indicated in view of the trend shown by these data. Measurements at the same frequencies are now being made on these same items but with saline solutions of various concentrations introduced between the capacitor and the RF outer conductor. Results of the later measurements will be available soon and should indicate the direction to proceed in further evaluating this component.

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1. EVALUATIONS OF PROTECTED MARK 7 MOD 0 IGNITION ELEMENT

1.1 RF Tests at 30 and 250 Mc

Since the inception of Contract N178-7830 (FIL Project B1805) revolutionary changes have been made in our methods of evaluating the sensitivity of EED's to RF excitation. Presently we are perfecting techniques which should enable precision RF firing tests to be performed throughout the frequency spectrum extending from dc to 10 Gc. Whereas a method developed on the above mentioned contract was limited to hot-wire bridge EED's which have no appreciable base loss, these new techniques are not so restricted.

The power measuring technique developed on this program, which we designate the "Voltage-Min-Max" method, provides a new approach toward RF testing above 500 Mc. This has been adequately documented in earlier reports. On the other hand, precision evaluations at lower frequencies are now possible due to development of a voltage-impedance power measurement procedure. Details of the firing test utilizing this technique are given in the following sections.

1.1.1 General Procedure for Low Frequency RF Initiator Testing

The general arrangement of basic equipment used in low-frequency evaluation tests is shown in Figure 1-1. Details of systems used at 30 and 250 Mc to fire the protected MARK 7 MOD 0 elements are appended. A generator with adequate power feeds energy to the EED termination by way of a relatively direct path which includes a number of necessary system elements.

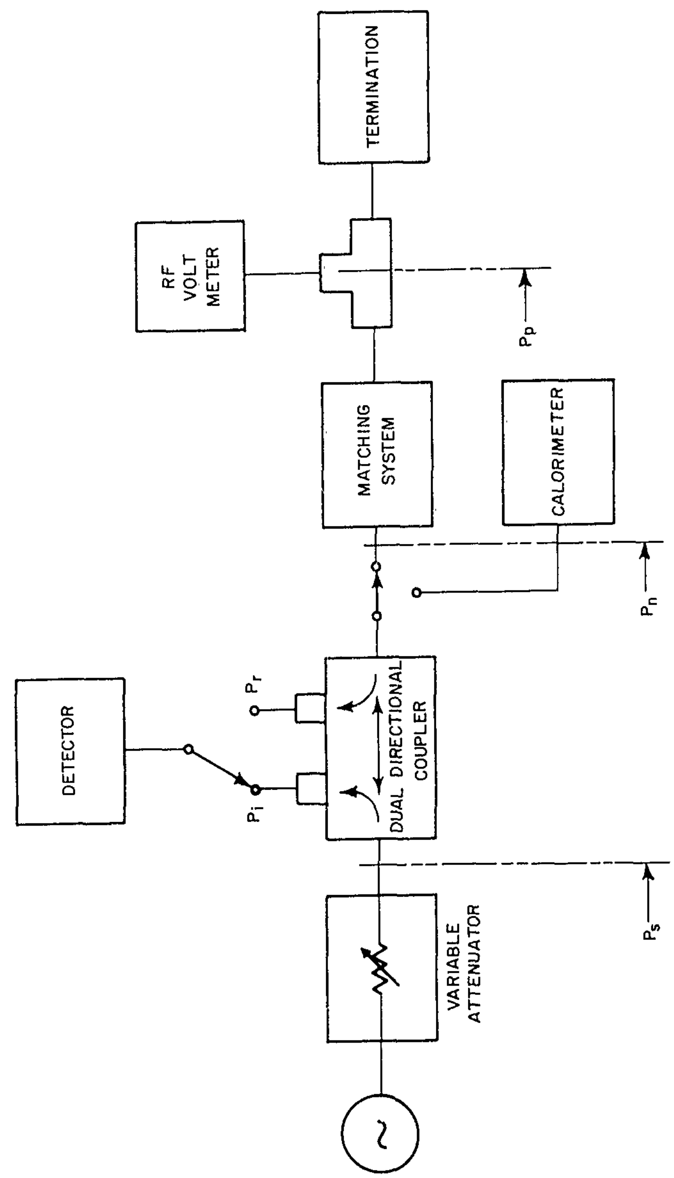

FIG. 1-1. BASIC LOW FREQUENCY FIRING SYSTEM

A variable attenuator is introduced to vary the power to the system. The directional coupler with its associated detector permits measurement of power flow in either direction. If the line is flat (matched) the reflected power is zero, and incident power is proportional to the system power. Since the terminating EED, in general will have an impedance differing considerably from that of the main transmission line system, we must introduce a matching system. Finally, to measure power at the input to the EED we introduce a transmission line "T", to which an RF voltmeter is connected.

In the arrangement just described it is a relatively simple task to determine the power flowing into the matched system (P_n); a calorimetric power meter permits this to be done within a 2% error. Either the incident-power-port detected signal can be calibrated against the calorimeter,or by alternately switching between calorimeter and system, the calorimeter itself can be used for a measure of P_n.

The difficult job is to measure the power at the EED's input terminals. The voltage-impedance technique will determine power at any point in the line, if the voltage and impedance can be determined at the point in question. Experimental evidence has been collected to show that the power (P_p) is equivalent to the power at the EED terminals.

Since the EED termination is likely to be present for only a short span of time it is not possible to use any method for determining its input power directly in conducting the RF firing test. It is necessary that a fixed power be delivered to a relatively fixed termination. Since the matched system can be expected to be little changed during the time of functioning for most EED's then it is expedient to monitor this power for testing. It is only necessary to relate this power to the power input to the EED. If power is kept at a very low level, a

live device can be excited and measurements of P_n and P_p determined as outlined above. Doing this for a number of items selected at random will give an average system calibration factor relating, as required, system input power to power delivered to the EED.

1.1.2 Results of Tests

Firing tests were performed on the lot of RF protected MARK 7 MOD 0 ignition elements at 30 and 250 Mc. Calibration was performed in the manner described in the preceding section. The system used at 30 Mc was found to be 56% efficient, while that at 250 Mc was almost perfect, so much so that it was calibrated at 100% efficiency.

During the actual firing, it was possible to monitor the calibration by keeping the voltage probe in place. Since tuning was performed at a low fixed power, and since the impedances of the ignition elements were observed to be essentially the same for all of the EED's measured, it was necessary, therefore, only to observe the relative deviation of the voltmeter reading as the EED's were successively subjected to tests. There was observable deviation around the average, in the 30 Mc test, while all the 250 Mc test results remained very near the 100% mark.

In performing the 30 Mc tests several minor problems necessitated the expenditure of a number of the ignition elements. Because the supply was limited, a 30 element test was accepted in place of the 40 item test requested. Since most of the problems were cleared up at the lower frequency it was a simple matter to obtain a 40 element test at 250 Mc. Results derived from these tests are given in Table 1-1. The given end points are calculated with 90% confidence. The actual test data are appended.

Table 1-1

30 AND 250 Mc FUNCTIONING LEVELS FOR PROTECTED MARK 7 MOD 0 IGNITION ELEMENT

Frequency (Mc)	Number of Units	Power for indicated functioning probability (watt) To system 5%	50%	95%	To EED 5%	50%	95%
30	30	0.612	0.805	1.059	0.343	0.451	0.593
250	43	1.092	1.158	1.233	1.092	1.158	1.233

These results are not inconsistent with evaluation data obtained during the development of this lot. More will be said about them in Section 2.

1.1.3 Base Loss Measurements

Included in the discussion of Section 1.1.1 was a means for measuring power delivered to any arbitrary termination. By resorting to techniques developed on an earlier program we may determine the power at the bridgewire. By calculating the ratio of bridgewire power to termination power, we can derive the base loss.

On contract N178-7830 we perfected a system for sensing the power at the bridgewire of an EED. This system uses a Clairex photo conductive cell. The cell system is calibrated to give the RF power by comparing the response of the system to comparable RF and dc power inputs.

When measurements were attempted at 30 Mc, the power indicated at the bridgewire was 1.14 times the power entering the base, an obvious impossibility. An analysis of the discrepancy suggested that the impedance value used in computing the base power could be in error. While making the Clairex cell system calibration we determined the dc resistance of the bridgewire at the power level used for comparison; it was found to be 1.3 ohms. This value was substituted for the real

part of the 30 Mc impedance, and the base power recalculated. It was then found that base power and bridge power were almost identical. This was a more reasonable comparison, since at this frequency the loss produced by the material used in the protected MARK 7 MOD 0 should be so little that it would be difficult to detect.

On the other hand, at 250 Mc we would expect the loss to approach a measurable value. Using the photoconductive cell and the voltage-impedance power measuring technique we were able to obtain the following data at this frequency.

Table 1-2

POWER LOSS IN PROTECTED MARK 7 BASE AT 250 Mc

P_p Power at probe (mw)	P_b Power at bridge (mw)	P_p/P_b	Power loss (db)	
863	268	3.11	4.93	
980	300	3.06	4.86	(ave = 4.87)
1120	339	3.02	4.81	

That these are reasonable results is obvious when the data point is plotted on a curve relating many loss measurements made at different frequencies. This correlation may be noted by referring to Figure 2-2, discussed in more detail in Section 2.

1.2 RF Tests at 3 Gc, CW and Pulsed

Our attempts at CW testing were limited to subjecting 10 ignition elements to a power input of 153 watts (system input of 170 watts, because system efficiency is 90%) for one second. This was achieved by pushing our power transmission system to its limit. In another test we allowed 10 elements to be subjected to 10 watts of CW power for 10 minutes. In neither case did an element fire, even though in the second test the system plumbing became uncomfortably hot.

For pulsed application it was necessary to keep the system average power level at or below 20 watts. Attempts to fire ignition elements were made with system power as high as 40 watts, but in doing so we destroyed a coupling. Five elements were energized with 18 watts input (at 90% efficiency 20 watts was the power to the system) and nothing was observed to happen.

1.3 Experiment with dc Preconditioning

In the recommended outline of tests of the protected MARK 7 MOD 0 elements was a test to determine the effect upon normal functioning of a lengthy exposure to a low level excitation. The 0.1% point determined with 90% confidence was chosen as a good choice for the biasing stimulus, which was to be applied for five minutes. Following this exposure the ignition elements would be fired in a dc functioning test, and the results compared to those from the elements not so treated.

The test plan called for preconditioning with dc, 3 Gc CW, and 3 Gc pulsed. It is hoped that any change brought about will be equally obvious irrespective of the form of the treatment, so that a simple dc test will suffice in the future. Because of the results presented in the previous section it will not be possible to perform the tests at 3 Gc; consideration is being given to shifting to 1 Gc. The dc preconditioning exposure was started this period.

For this lot of MARK 7's, a mean firing current of 597 milliamperes was determined for 10 sec dc pulses. The standard deviation was 0.009 log units. From these and other data obtained in the firing test we compute the 0.1% point with 90% confidence to be 546 milliamperes, remarkably close to the mean.

Using this power level, three elements were conditioned, but a fourth one fired. Though the actual functioning time was not obtained, it was observed to be very short. At this functioning level we would

expect 1 in 1000 devices to fire; one in four caused the operator to question his equipment and to halt the testing until a check of the system could be made. All indications are that the equipment used in this test was in order, and the calculated level was correct. There being no reason to suspect other errors the test will be continued, hopefully without another functioning.

2. SUMMARY OF PROTECTED MARK 7 MOD 0 EVALUATION RESULTS

With the exception of one test at dc to determine the alteration to normal functioning brought about by a low-level long-duration exposure, a testing program for the protected MARK 7 MOD 0 ignition element in accordance with the test outline has been completed. Tests could not be performed at 3 Gc as planned, because the high losses made excessive power demands on equipment. Before indicating alternate tests it would be well to review the data that have been collected on this item.

2.1 RF Firing Test Results

All of the data resulting from RF functioning tests are displayed in Figure 2-1. The responses of both the standard (unattenuated) and the protected ignition elements are contrasted to the minimum continuous dc power required.

Much of these data were collected by use of outdated firing techniques, which determine the power input to the matched system terminated by the ignition element. Hence, these power levels are greater than or at best, equal to the actual power delivered to the EED leads. The difference, if it were known, between the power plotted and the power fed to the element, corresponds to the dissipation in the matched system, power which should not be charged to the EED. At 30 and 250 Mc, due to advanced techniques, this system loss is not included in the corrected data point (points shown boxed in the figure).

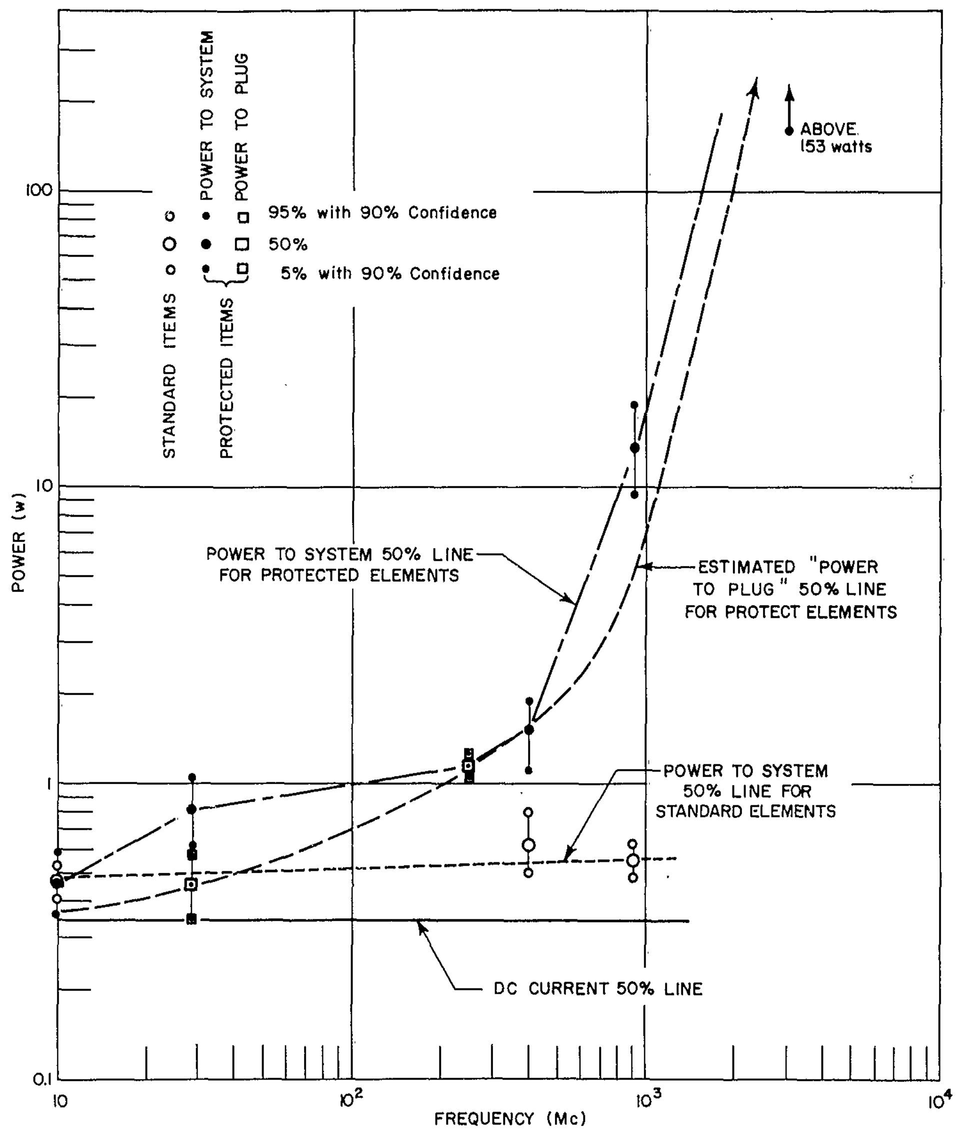

FIG. 2-1. SUMMARY OF MARK 7 MOD 0 IGNITION ELEMENT RF FIRING DATA

Indications are that the data given at 400 Mc for the protected lot are reasonably close to the actual power to the item. Since the systems used for both 400 and 250 Mc tests are almost identical, the system efficiencies could be closely related provided the change in frequency does not cause a drastic change in the character of the load. Had a data point been obtained at 3 Gc it would have been plotted above 153 watts. The assumption that a smooth curve is to be obtained by connecting the data points leads to the conclusion that the data at 900 Mc may also be a reasonable estimate of the power actually delivered to the item's leads. Since the lossy character of the attenuator incorporated into this item is described by a 53° slope straight line on a log plot of frequency vs loss, this is a realistic expectation.

Because of the limited data available for the standard ignition element it is not possible to make any firm statements relevant to its characteristic response to RF. The data does indicate that the item is a little less sensitive to RF than to dc, at least out to 1 Gc. Though not shown, data are available for the response of this item at 3 Gc pulsed; a mean average power of about 5 watts being required for 50% functioning. These data also are measures of power to the system; power to the ignition element is assumed to be considerably less, since the old system used to fire this test can be expected to be relatively lossy.

A comparison of the results for both the standard and the protected items points up the merit of the latter. Though little extra protection is provided at lower frequencies, the difference becomes obvious at 400 Mc and higher. The nature of the data available at 3 Gc indicates a very high level of protection.

2.2 Base Loss and Attenuation Determinations

All data obtained by experiment with inert items are contained in Figure 2-2, together with attenuation values derived from the firing tests just discussed. The most significant observation to be made of these data is that there is very good correlation between results derived from expending large quantities of devices and those from instrumented tests with only a few.

The data points at 80 and 200 Mc were derived from measurements of impedance of plug assemblies from which an impedance model (symmetrical T network) was constructed. Values of power loss were computed from this model network terminated in a bridgewire represented as a one-ohm dissipative load. At 250 Mc there are two data points, one from calculation based upon the firing results, the other from experimental tests utilizing a photoconductive cell to detect power at the bridgewire. Rounding out the plug loss measurements is the data point at 500 Mc, the average for matched attenuation measurements made on a large sample from the development lot.

The straight-line curve at the top of the figure is reproduced from data obtained from a special set of protected plugs. These were made by a new acetone phosphate process for insulating the carbonyl iron; the production lot was made with water phosphate bath. The curve is included for two reasons: (1) to show the slope of the power loss-frequency curve to be expected for this item, and (2) to show the order of magnitude of improvement which could be made in the protected items.

As stated previously, there is very good correlation between the experimental data and firing data, at least below 500 Mc. Additional data at higher frequencies would be of value in defining the extent to which we might profitably use instrumented items; these tests are proposed in the following sections.

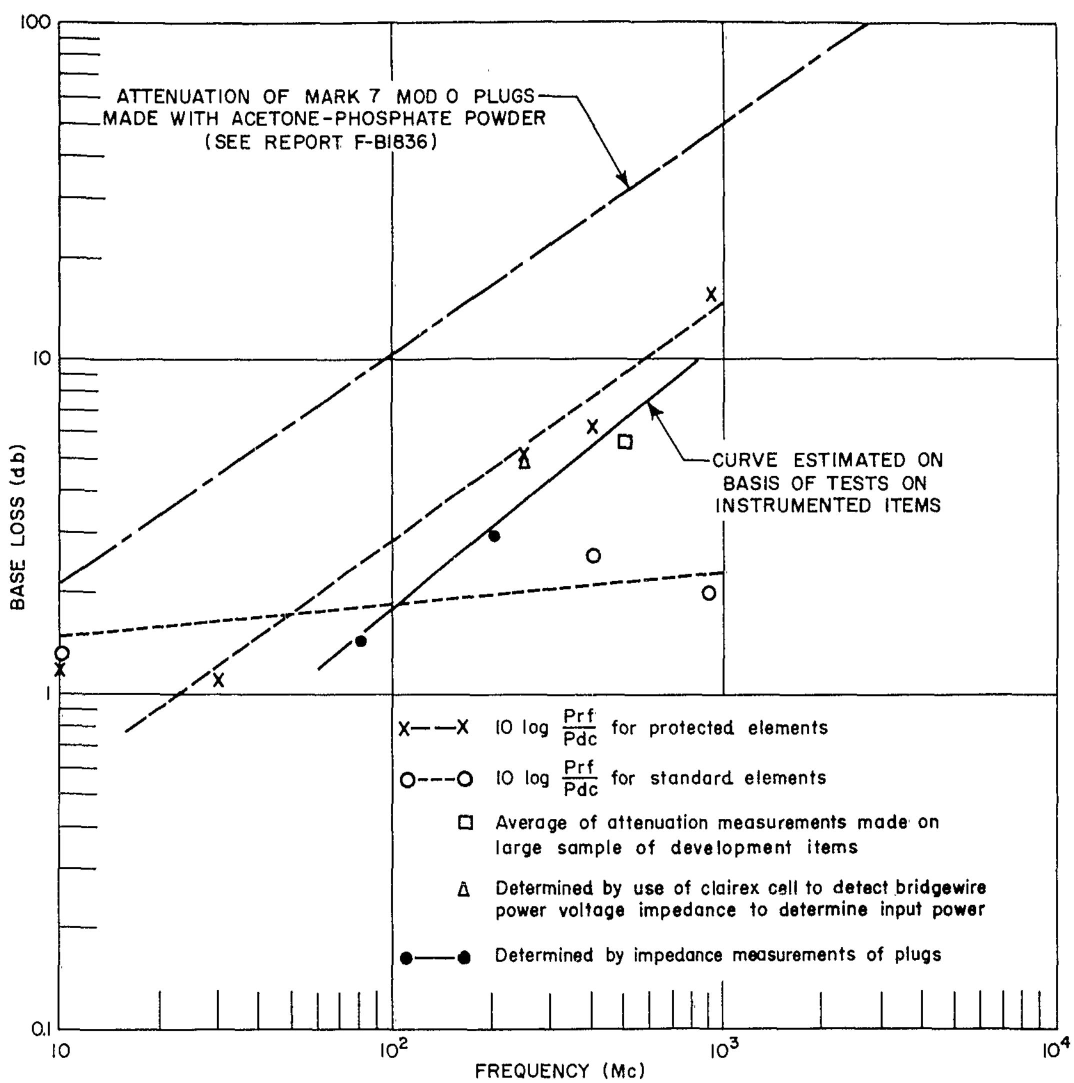

FIG. 2-2. SUMMARY OF PROTECTED MARK 7 MOD 0 IGNITION ELEMENT BASE LOSS DETERMINATIONS

The data given for the attenuation of the standard item must be viewed with caution, since system loss is included. Exclusion of the system loss part could be expected to drop all points to values below 1 db.

2.3 Additional Tests Recommended

Cook-off experiments at 3 Gc were called for in the HERO test schedule for the protected MARK 7 MOD 0 ignition element. However, the item's high loss at this frequency put our high power system to task.

Not being able to conduct a standard firing test we were unable to predict a reasonable level to use for the investigation of cook-off possibilities. Ordinarily we expose a number of devices to the computed 0.1% functioning level for 5 minutes or longer.

A 10-watt 10-minute test produced a certain amount of heating, but we cannot be certain that it was centered in the ignition element. Moreover, it was apparently well below that required for cook-off. As an alternative we propose to investigate cook-off at 1 Gc.

It now seems that the sensitivity test at 1 Gc could be repeated to advantage. The data available (at 900 Mc) are for power into a matched system; it would be better to know the power into the leads. In Section 2.1 we stated that the older data appeared to be the result of an evaluation performed on a highly efficient system; we now propose to verify this conjecture.

The HERO test schedule did not limit us to 3 Gc for the preconditioning experiment, but we felt it would be advantageous to combine this with the cook-off test, since both involve exposures to the 0.1% firing level. Our choice of the higher frequency was also prompted by the thought that effects upon normal responses due to preconditioning might be related to the amount of plug loss, i.e. a lossy item may be more seriously altered than a non-lossy one. In view of the power limitations at 3 Gc we propose to perform this test, also, at 1 Gc.

3. EVALUATION OF TANTALUM CAPACITORS

It was mentioned last period that we were in the process of investigating the lossy character of a tantalum feed-through capacitor. Measurements of input impedance with various terminations at 0.5, 1, 5 and 10 Mc were made as a start toward defining the loss-frequency character of this component. From these measurements, with the aid of a high speed computer, we compute both the load which, if placed across the output terminals of this feed-through capacitor, would minimize the losses realized in the capacitor, and the amount of these losses. Details of this technique were given in Report P-B1981-6*.

Although ten units were prepared for these measurements only five were used. Individual variations in the impedance data were so small that it was deemed unnecessary to use all ten. Four readings are made on each individual element; three are required for the calculation of attenuation, and one is added to check on error. The results are shown in Figure 3-1.

These data are interesting because they show relatively high loss for reasonably low frequencies. Also, they show that the loss does not increase with frequency as does that for carbonyl iron, but will have maxima and minima. There may be, for example, individuals in this group with loss much less than that indicated at 1 Mc, but at some other frequency. Though all of the individual samples seem to be typified by this curve, there may be some deviations. Additional measurements will be made at intermediate points to investigate this possibility.

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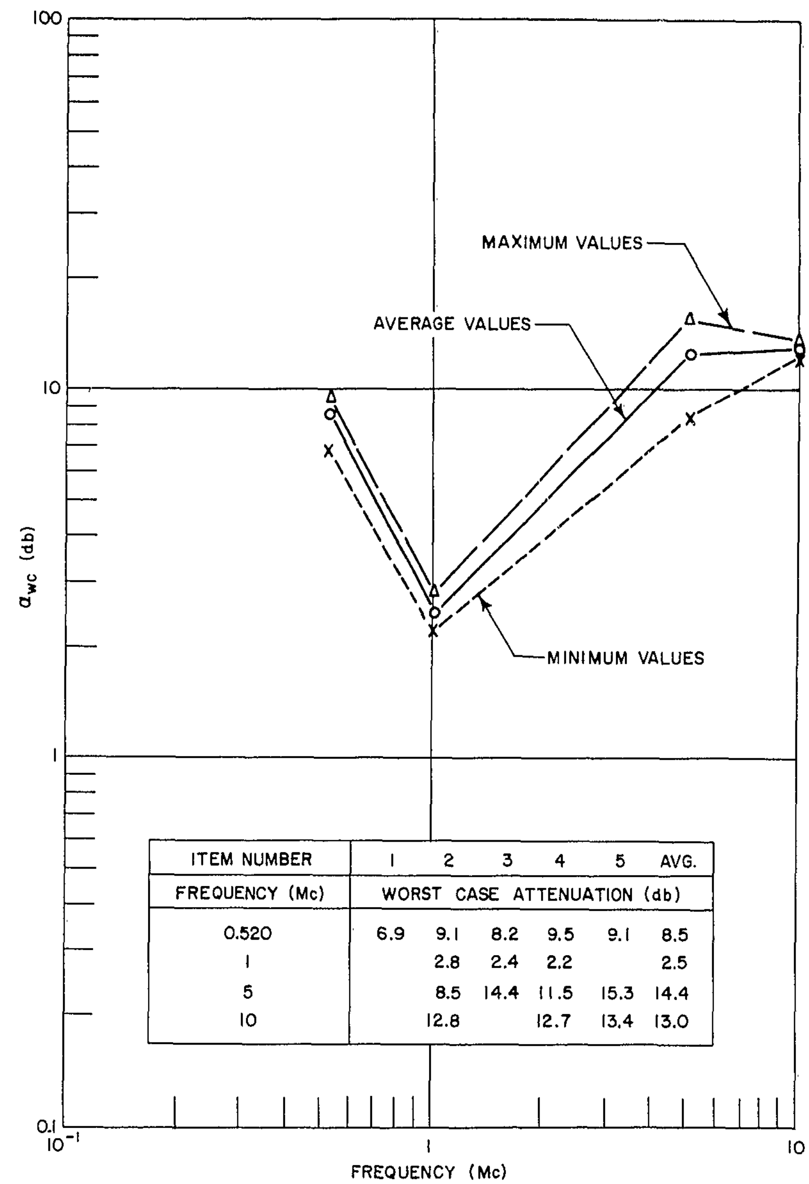
*Monthly Progress Report P-B1981-6, "Development of Broad-Band Electromagnetic Absorbers for Electroexplosive Devices" by P. F. Mohrbach and R. F. Wood, December 31, 1962, Contract N178-8087.



ITEM NUMBER	1	2	3	4	5	AVG.
FREQUENCY (Mc)	WORST CASE ATTENUATION (db)					
0.520	6.9	9.1	8.2	9.5	9.1	8.5
1		2.8	2.4	2.2		2.5
5		8.5	14.4	11.5	15.3	14.4
10		12.8		12.7	13.4	13.0

FIG. 3-1. ATTENUATION VALUES FOR TANTALUM CAPACITORS

Prior to obtaining these results provisions were made so that saline solution could be interposed between the capacitor and the coaxial line outer conductor. The mount designed to permit this experiment as requested by the Naval Weapons Laboratory is shown in Figure 3-2. Because the capacitors were all firmly mounted in the universal mount adaptor it was necessary to include it in the assembly. Should it appear that the mount has some effect upon the data, the brass piece could be removed without harm to the capacitor.

Measurements have been made on the identical capacitors evaluated previously, each with three different concentrations of salt water in the special fitting. The solutions had 400, 250 and 100 grams of salt per liter of distilled water respectively. Measurements of the resultant conductivity (σ) are to be made.

The impedance measurements have all been made, and are to be reduced when the computer is again available. A moderate change in the loss is anticipated since the impedance measurements show marked differences for different saline mediums.

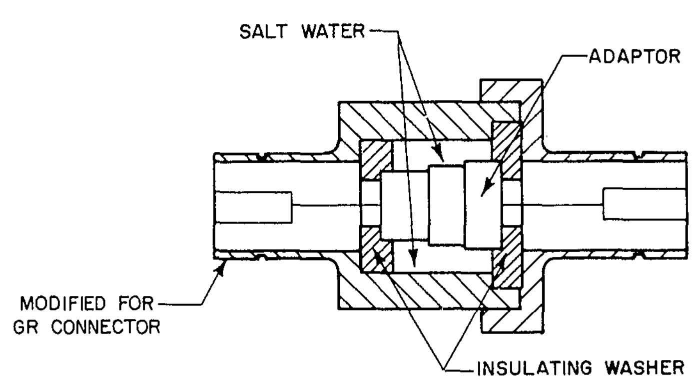


FIG. 3-2. SALINE MOUNT FOR TANTALUM CAPACITOR

ACKNOWLEDGEMENTS

Acknowledgement is made of the contribution of Charles L. Stonecypher, George C. Roatche and Kenneth S. Fertner to the work of Section 1. For the material documented in Section 3 credit goes to Anthony Pellegrino, Rammie H. Thompson and Robert F. Wood.

Paul F. Mohrbach
Group Leader

Norman P. Faunce
Project Leader

Approved by:

E. H. Hannum, Manager
Applied Physics Laboratory

Francis L. Jackson
Director of Laboratories

APPENDICES

Appendix A - Equipment Used at 50 to 30 Mc

Appendix B - Equipment Used at 250 to 500 Mc

Appendix C - 30 Mc Bruceton Data Form

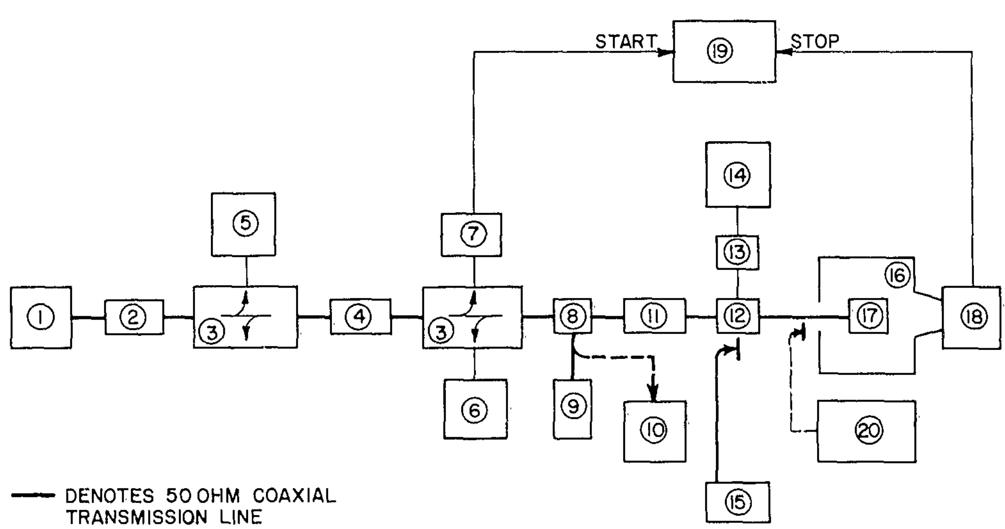
Appendix D - 250 Mc Bruceton Data Form

Appendix E - Power Loss of Protected MARK 7 MOD 0 Ignition Element Determined from RF Firing Data

APPENDIX A

EQUIPMENT USED AT 5 to 30 Mc (CW)

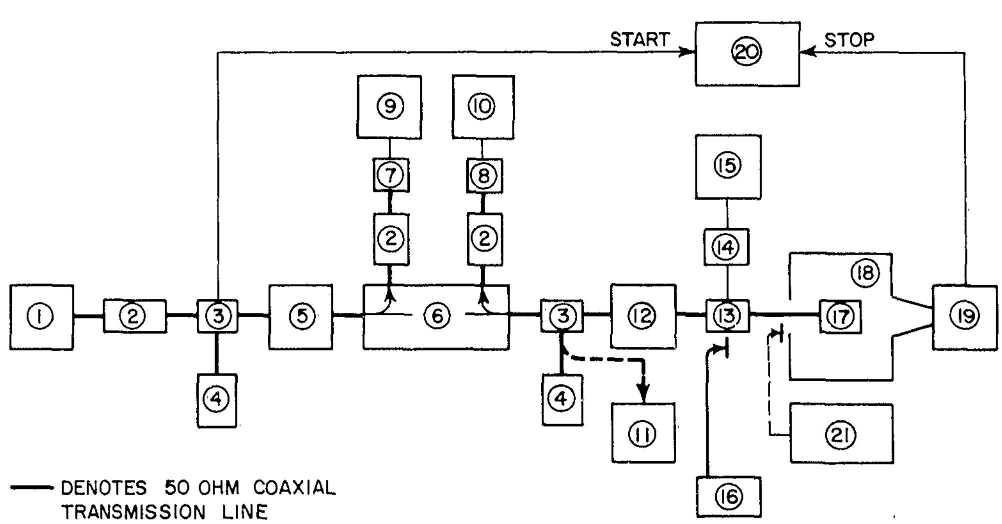
1. RF Power Generator: Johnson Viking II amateur transmitter (modified); 0 to 100 w at 5 to 30 Mc.
2. Fixed Power Attenuator: Resistive T network; 6 db attenuation; forced air cooled developed by The Franklin Institute.
3. Directional Couplers (2): M.C. Jones Model 263 dual coupler: 1000 w at 0.5 to 225 Mc.
4. Fixed Attenuator: Microlab Model AD-03N, AD-06N, AD-10N, and AD-20N; 3, 6, 10 and 20 db attenuators; 15 w at dc to 4 Gc; (employed as necessary for proper power level).
5. Power Indicator (forward power monitor): developed by The Franklin Institute. Comprises Triplett Model 626 microammeter (200 micro amp. 180 ohms) and switch-selected resistors.
6. VSWR Indicator (reflected power): KinTel Model 204A electronic galvanometer.
7. DC Amplifier (chronograph start): Tektronix Model 112.
8. RF Switch: Transco Model 11300; solenoid operated.
9. High Power Termination: Microlab Model TB-5MN 50 ohm 10 w termination: Sierra Electronics Model 160-20MN (20 watts).
10. Power Standard: Hewlett-Packard Model 434A Calorimetric power meter; 10 mw to 10 w at dc to 12.4 Gc, with internal power source for calibration.
11. Impedance Matching Network: Adjustable capacitive and inductive components to achieve an impedance match between the EED and 50 ohm line. Developed by The Franklin Institute.
12. Coaxial Tee: General Radio Type 874-T coupling element.
13. Voltage Probe: Hewlett Packard Type 411A-21B probe to be used in conjunction with Model 411A RF Millivoltmeter.
14. RF Millivoltmeter: Hewlett Packard Model 411A millivoltmeter. 10 mv to 10 volts rms at .5 to 1000 Mc.
15. Impedance Bridge: General Radio Type 916A RF bridge. 0.4 to 60 Mc.
16. Firing Chamber: Steel chamber specially designed for testing electroexplosive devices (includes safety shields, electrical interlocks, ventilation system, etc.).
17. RF Mount: Special mounting fixtures are made for each type of electroexplosive tested.
18. Photo-Detector (chronograph stop): Developed by The Franklin Institute. It employs a photo-multiplier tube which is triggered by the light output of the electroexplosive device as it is initiated.
19. Chronograph: Beckman/Berkeley Model 7370R universal EPUT and timer.
20. Resistance Meter: Keithley Model 502 milliohmmeter. .001 - 1000 ohms.



APPENDIX B

EQUIPMENT USED AT 250 - 500 Mc (CW)

1. RF Power Generator: APQ-2 airborne jamming transmitter (modified); 0 to 12 w at 250 to 500 Mc.
2. Fixed Attenuators: Microlab Models AD-03N, AD-06N, AD-10N, AD-20N: 3, 6, 10 and 20 db attenuators (employed as necessary for proper power level).
3. RF Switch: Transco Model 11300, solenoid operated.
4. High Power Termination: Microlab Model TB-5MN, 50 ohm termination 10 w dc to 5 Gc, or Sierra Electronics Model 160-20MN (20 watts).
5. Signal Detector (chronograph start): Microlab Model HXN-10 Signal sampler (contains crystal detector).
6. Directional Couplers (incident and reflected power): Hewlett-Packard dual directional couplers Model 764D (216 to 450 Mc)
7. RF Detector (incident power): Hewlett-Packard Model 477B thermistor mount; 0.1 to 10 mw at 10 to 10,000 Mc.
8. RF Detector (reflected power): Hewlett-Packard Model 420B crystal detector: 10 to 12,500 Mc.
9. Indicator (incident power): Hewlett-Packard Model 430C or 431B microwave power meter: 10 microwatt to 10 milliwatts. (431B) 100 µw to 10 mw (430C)
10. Indicator (reflected power): KinTel Model 204A electronic galvanometer.
11. Power standard: Hewlett-Packard Model 434A calorimetric power meter: 10 mw to 10 w at dc to 12.4 Gc, with power source for calibration.
12. Impedance Matching Network: Microlab Model SL-03N stub stretcher; 250 to 10,000 Mc.
13. Coaxial Tee: General Radio Type 874-T Coupling Element.
14. Voltage Probe: Hewlett-Packard Type 411A-21B probe to be used in conjunction with Model 411A RF Millivoltmeter.
15. RF Millivoltmeter: Hewlett-Packard Model 411A millivoltmeter. 10 mv to 10 vac rms at .5 to 1000 Mc.
16. Impedance Bridge: General Radio Type 1607A transfer function and immittance bridge 25 - 1500 Mc.
17. RF Mount: Special mounting fixtures are made for each type of electro-explosive tested.
18. Firing Chamber: Steel chamber specially designed for testing electroexplosive devices (include safety shields, electrical interlocks, ventilation system, etc.).
19. Photo-detector (chronograph stop): Developed by The Franklin Institute. It employs a photo-multiplier tube which is triggered by the light output of the electroexplosive device as it is initiated.
20. Chronograph: Beckman/Berkeley Model 7370R universal EPUT and timer.
21. Resistance Meter: Keithley Model 502 milliohmmeter .001 - 1000 ohms.



APPENDIX C

30 Mc BRUCETON DATA FORM

ITEM NO.	Functioning Levels (ζ): 673	712	754	800	847	897	950	FUNCT. TIME (secs)	RESISTANCE (Ω)
1					X			0.916242	
2				X				.1375496	
3			O					—	
4				X				2.185308	
5			X					1.721440	
6		O						—	
7			O					—	
8				O				—	
9					X			.8—	
10				O				—	
11					X			.151141	
12				O				—	
13					X			1.138886	
14				O				—	
15					X			.217459	
16				X				1.093735	
17			X					1.582138	
18		O						—	
19			O					—	
20				O				—	
21					O			—	
22						O		—	
23							X	.701227	
24						X		.206525	
25					X			.688370	
26				X				1.163484	
27			O					—	
28				O				—	
29					X			<2.0	
30				X				1.442342	
31									
32									
33									
34									
35									
36									
37									
38									
39									
40									
41									
42									
43									
44									
45									
46									
47									
48									
49									
50									
X		0	2	5	7	1	1	n_x = 16	
O		2	4	6	1	1	0	n_o = 14	

i	i^2	n_o	n_x	ζ = mw
0	0	2	0	712
1	1	4	2	754
2	4	6	5	800
3	9	1	7	847
4	16	1	1	897
5	25	0	1	950
6	36			
Totals:		N_o = 14	N_x = 16	

Special Parameters

$c = (\log \zeta)_{i=0}$ = 2.85248

$d = (\log \zeta)_{i+1} - (\log \zeta)_i$ = 0.025

Primary Statistics

$A = \Sigma\, i n$

$B = \Sigma\, i^2 n$

$M = (NB - A^2)/N^2$

$m = c + d\,(A/N \pm ½)^*$

$\sigma = 1.62\, d\,(M + 0.029)\sqrt{\frac{N}{N-1}}$ **

*Use + for "o's;" - for "x's"

**Valid for M ⩾ 0.3 only, otherwise consult 'Bruceton Report' (AMP Report No. 101.1R, "Statistical Analysis for A New Procedure in Sensitivity Experiments" July, 1944) File No. Ma-1

	For "o's"	For "x's"
A =	23	42
B =	53	126
M =	1.0867	0.9843
m =	2.90605	2.90560
σ =	.04688	.04238

Secondary Statistics

$$m = \frac{N_o\, m_o + N_x\, m_x}{N_o + N_x} = 2.9058$$

$$\sigma = \sqrt{\frac{N_o\, \sigma_o^2 + N_x\, \sigma_x^2}{N_o + N_x}} = .04453$$

ζ = Antilog m = 805.0 mw

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HUMIDITY / TEMP. Room Conditions

LOT NO. A2203 B1836

ITEM Protected Mark 7 Mod 0

FREQUENCY 29 MC

PULSE WIDTH —

REP. RATE —

TYPE OF TEST RF Bracketing

TEST NO. 1

Probability Levels	Confidence Level
P% = 95	X% = 90
100-P% = 5	

m = 2.9058	k_p ② = 1.645
σ = .04453	k_x ② = 1.282
d = 0.025	G ③ = .948
$S = \frac{\sigma}{d}$ = 1.7812	G^2 = .8987
N = 30	H ③ = 1.66
n ① = 15	H^2 = 2.7556

① $n = \frac{N}{2}$ when N is <u>even</u> integer

$n = \frac{N+1}{2}$ when N is <u>odd</u> integer

② From BR*, p. 19, at given P or X

③ From BR* for G & H versus S, Use Graphs III & IV. When S ≥ .5, and Graph V When S < .5

Confidence Interval (Y)

$$Y = k_x \left(\frac{n+1.2}{n}\right)\left(\frac{G^2 + H^2 k_p^{\,2}}{n}\right)^{1/2}\sigma$$

= .04601

Final Calculations

(95%) (90% Conf) = $m + k_p\sigma + Y$

= 3.02506 log units

= 1059 mw

(5%) (90% Conf) = $m - k_p\sigma - Y$

= 2.78654 log units

= 611.7 mw

CALCULATIONS: P.McK

APPENDIX D

250 Mc BRUCETON DATA FORM

Functioning Levels (ζ) 1.10	1.14	1.18	1.22	FUNCT. TIME (secs)	RESISTANCE (Ω)	ITEM NO.
O				—		1
	O			—		2
		X		1.333464		3
	O			—		4
		X		.053537		5
	X			1.578159		6
O				—		7
	X			.223192		8
O				—		9
	O			—		10
		X		1.240796		11
	O			—		12
		X		.619557		13
	O			—		14
		X		.156602		15
	O			—		16
		X		1.218365		17
	O			—		18
		X		1.379418		19
	O			—		20
		O		—		21
			X	.384135		22
		O		—		23
			X	.676328		24
		O		—		25
			X	.447738		26
		O		—		27
			X	.366872		28
		X		1.596048		29
	O			—		30
		X		1.280031		31
	O			—		32
		O		—		33
			X	1.527692		34
		X		.792466		35
	X			.639837		36
O						37
	O					38
		X		.691761		39
	O					40
		X		.811046		41
	X			1.554248		42
X				2.072241		43
						44
						45
						46
						47
						48
						49
						50
1	4	12	5	n_x = 22		X
4	12	5	0	n_o = 21		O

i	i^2	n_o	n_x	ζ = W
0	0	4	1	1.10
1	1	12	9	1.14
2	4	5	12	1.18
3	9	0	5	1.22
4	16			
5	25			
6	36			
Totals:		N_o = 21	N_x = 22	

Special Parameters

$c = (\log \zeta)_{i=0}$ = 0.04139

$d = (\log \zeta)_{i+1} - (\log \zeta)_i$ = 0.015

Primary Statistics

$A = \Sigma\, i\, n$

$B = \Sigma\, i^2 n$

$M = (NB - A^2)/N^2$

$m = c + d\,(A/N \pm ½)^*$

$\sigma = 1.62\, d\,(M + 0.029)\sqrt{\frac{N}{N-1}}$ **

*Use + for "o's;" - for "x's"

**Valid for M ⩾ 0.3 only, otherwise consult 'Bruceton Report' (AMP Report No. 101.1R, "Statistical Analysis for A New Procedure in Sensitivity Experiments" July, 1944) File No. Mn-1

	For "o's"	For "x's"
A =	22	43
B =	32	97
M =	.426302	.607438
m =	.06460	.06320
σ =	.01133	.01582

Secondary Statistics

$$m = \frac{N_o m_o + N_x m_x}{N_o + N_x} = .06388$$

$$\sigma = \sqrt{\frac{N_o \sigma_o^2 + N_x \sigma_x^2}{N_o + N_x}} = .01381$$

ζ = Antilog m = 1.158 watt

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HUMIDITY / TEMP. Room Condition

LOT NO. 42203 G1836

ITEM RF Protected MARK 7 MOD 0

FREQUENCY 250 Mc

PULSE WIDTH —

REP. RATE —

TYPE OF TEST RF Bruceton

TEST NO.

Probability Levels	Confidence Level
P% = 95	X% = 90
100-P% = 5	
m = .06460	k_p② = 1.645
σ = .01133	k_x② = 1.282
d = .015	G③ = 1.05
$S = \frac{\sigma}{d}$ = .75533	G^2 = 1.1025
N = 43	H③ = 1.29
n① = 22	H^2 = 1.6641

① $n = \frac{N}{2}$ when N is <u>even</u> integer

$n = \frac{N+1}{2}$ when N is <u>odd</u> integer

② From BR*, p. 19, at given P or X

③ From BR* for G & H versus S. Use Graphs III & IV. When S ≥ .5, and Graph V When S < .5

Confidence Interval (Y)

$$Y = k_x \left(\frac{n+1.2}{n}\right)\left(\frac{G^2 + H^2 k_p^{\,2}}{n}\right)^{1/2}\sigma$$

= .0076972

Final Calculations

(95%) (90% Conf) = $m + k_p\sigma + Y$

= .090934 log units

= 1.233 watt

(5%) (90% Conf) = $m - k_p\sigma - Y$

= .038265 log units

= 1.092 watt

CALCULATIONS P.McK

APPENDIX E

Power Loss of Protected MARK 7 MOD 0 Ignition Element Determined from RF Firing Data

Frequency (mc)	Power (mw) for 50% Probability of Functioning		RF to DC Power Ratio		Power Loss (db)	
	Std.	Protected	Std.	Protected	Std.	Protected
10	468	459	1.34	1.31	1.3	1.2
30	-	451	-	1.29	-	1.1
250	-	1158	-	3.31	-	5.2
400	636	1506	1.82	4.31	2.6	6.3
900	560	13700	1.60	39.2	2.0	15.9
3000*	4547*	-	13.0	-	11.1	-

*Average power for pulsed RF stimuli

$$\text{Power Loss (db)} = 10 \log \frac{\text{RF power for 50\% functioning}}{\text{dc power for 50\% functioning}}$$

$$\text{dc power for 50\% functioning} = 349 \text{ mw} = (.597)^2 \times .979$$

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